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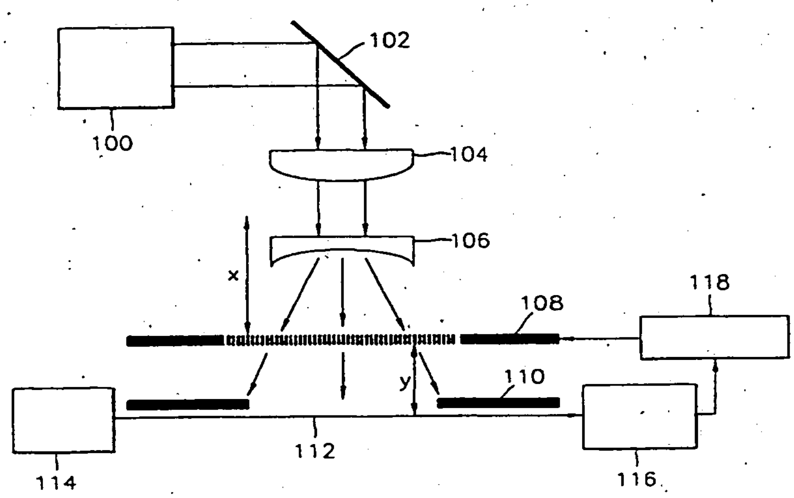

(57) Abstract

An apparatus for manufacturing a long-period fiber grating and a two-band long-period fiber grating manufacturing apparatus using the same are provided. The apparatus includes a light source (100) for generating the UV laser light, a mirror (102) for reflecting the UV laser light generated in the light source (100) at a predetermined angle and changing the traveling path thereof, a lens (104) for focusing the laser light whose traveling path is changed by the mirror (102), a dispersing unit (106) for dispersing the laser light passed through the lens (104), and an amplitude mask (108) positioned between the dispersing unit (106) and the optical fiber (112), and having a transmission region in which the dispersed laser light is periodically transmitted to the optical fiber (112). The bandwidth of a long-period fiber grating can be adjusted by adjusting the size of a laser beam irradiated into an optical fiber (112). Also, amplitude masks can be easily manufactured at low cost and damage threshold power thereof is high.

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APPARATUS FOR MANUFACTURING LONG-PERIOD FIBER GRATINGS AND APPARATUS FOR MANUFACTURING TWO-BAND LONG-PERIOD FIBER GRATINGS USING THE SAME

Technical Field

The present invention relates to an apparatus for manufacturing long-period fiber gratings, and an apparatus for manufacturing two-band long-period fiber gratings using the same.

Background Art

A long-period fiber grating couples a fundamental core mode to the cladding lead modes. Since the long-period fiber grating is not of a reflection type, it is advantageous for flattening the gain thereof.

Long-period fiber gratings are typically manufactured by periodically varying the refractive index of the core of an optical fiber which is sensitive to UV rays. In other words, the portion of the optical fiber core exposed to UV rays exhibits an increase in the refractive index and the non-exposed portion exhibits no change in the refractive index, so that a periodic change in the refractive index occurs. Coupling will occur in the core of an optical fiber under the condition expressed in Equation (1):

$$\beta_{co} - \beta_{cl}^{n} = \frac{2\pi}{\Lambda} \quad \ldots (1)$$

where β_{co} is the propagation constant of a core mode, β_{cl}^{n} is the propagation constant of a cladding mode and Λ is the grating period of the optical fiber.

When β is substituted with $2\pi \frac{n}{\lambda}$, where, n is the effective refractive index, Equation (1) can be written as difference between refractive indices of the core mode and the cladding mode $(n_{co} - n_{cl}^{n})$ equals to $\frac{\lambda}{\Lambda}$. Therefore, coupling wavelength

λ depends on the grating period Λ and the refractive index difference $n_{co} - n_{cl}^{n}$. For a fixed grating period Λ, coupling wavelength λ changes with $n_{co} - n_{cl}^{n}$ and the refractive index difference which can be obtained by appropriately irradiating UV laser into the optical fiber which is sensitive to UV rays.

If the UV laser is irradiated into the photosensitive optical fiber, the refractive index of the core of the optical fiber increases and as a result, the coupling occurs at the longer wavelength. A long-period fiber grating is manufactured by focusing UV laser such as an excimer laser in the x- or y-axis using a cylindrical lens and irradiating the same into a photosensitive optical fiber through an amplitude mask having a period Λ. In the case of the excimer laser with a $10 \times 30 mm$ beam size, the beam is largest when it is focused to a rectangular axis of 30 mm long excimer laser.

Here, it is important for the amplitude mask to have an accurate periodicity. In order to attain an accurate periodicity of the amplitude mask, various methods are employed. One of them is a method in which a single slit or optical fiber is installed in a translation stage and is then shifted by a desired period to irradiate laser light thereon. The single slit has advantages in that its periodicity is accurate and arbitrarily adjusted. However, according to this method, since the width of the slit is fixed, a duty cycle which is a ratio of a transmitted domain of light and a non-transmitted domain of light is not constant when the period of a long-period fiber grating is changed. Also, since the refractive index change is obtained point by point using a slit, a much time is required and large beam of laser light cannot be effectively utilized. Further, in order to accurately design of a desired filter spectrum, it is necessary to know the precise change in refractive indices per pulse, and an expensive translation stage is necessary.

Alternatively, in order to make the periodicity of a mask accurate, the mask can be manufactured by patterning with chrome on a silica. However, according to this method, the mask manufacturing process is complicated and costly. Also, since the period of the mask is fixed, only a single spectrum can be designed using a mask. Further, in this case, since the damage threshold power for this type of mask is low,

the excimer laser of high power cannot be effectively used.

Another method is to use multiple slits. The process for preparing a mask is simple and the costs therefor are low. However, since an error of one mask periodicity caused during laser treatment is very large, that is, $\pm 5\mu m$, an accurate spectrum design cannot be achieved easily. Also, since the period is fixed, the spectrums which can be designed are limited.

In general, the gain curve of an EDFA can be flattened when two or three different long-period fiber gratings, which means two or three different mask periods are necessary. Because the gain curve depends on the input signal light power, pump power, rare earth dopant rate, glass matrix, fiber length and so on, as many mask periods as possible are necessary.

Disclosure of the Invention

To solve the above problems, it is an objective of the present invention to provide an apparatus for manufacturing long-period fiber gratings for adjusting the periods of gratings written on an optical fiber by providing a concave lens for dispersing incident light and an amplitude mask having a predetermined period and changing the position of the amplitude mask, and an apparatus for manufacturing two-band long-period fiber gratings using the same.

Accordingly, to achieve the above objective, there is provided an apparatus for manufacturing a long-period fiber grating for periodically varying the refractive index of a core of an optical fiber by periodically irradiating UV laser light into the optical fiber, the apparatus including a light source for generating the UV laser light, a mirror for reflecting the UV laser light generated in the light source at a predetermined angle and changing the traveling path thereof, a lens for focusing the laser light whose traveling path is changed by the mirror, a dispersing unit for dispersing the laser light passed through the lens, and an amplitude mask positioned between the dispersing unit and the optical fiber, and having a transmission region in which the dispersed laser light is periodically transmitted to the optical fiber.

According to another aspect of the present invention, there is provided an apparatus for manufacturing a long-period fiber grating for periodically varying the

refractive index of a core of an optical fiber by periodically irradiating UV laser light into the optical fiber, the apparatus including a light source for generating the UV laser light, a mirror for reflecting the UV laser light generated in the light source at a predetermined angle and changing the traveling path thereof, a lens for focusing the laser light whose traveling path is changed by the mirror, a dispersing unit for dispersing the laser light passed through the lens, and an amplitude mask positioned between the dispersing unit and the optical fiber, and having a transmission region in which the dispersed laser light is periodically transmitted to the optical fiber, a measuring unit for measuring coupling peaks of a long-period fiber grating written on the optical fiber, and a controller for adjusting the position of the amplitude mask for obtaining a desired coupling peak wavelength in accordance with the coupling peak wavelengths measured by the measuring unit.

According to still another aspect of the present invention, there is provided an apparatus for manufacturing a two-band long-period fiber grating having different periods by aligning first and second amplitude masks having periodically repeated transmission regions and located at different positions from each other in the length direction of an optical fiber, in which UV laser light is irradiated into the two amplitude masks, the apparatus including a first long-period fiber grating manufacturing unit for determining the period of a first long-period fiber grating to be written on the optical fiber by adjusting the distance between the first amplitude mask and the optical fiber, and writing the first long-period fiber grating having a predetermined period on the optical fiber, a second long-period fiber grating manufacturing unit for determining the period of a second long-period fiber grating to be written on the optical fiber by adjusting the distance between the second amplitude mask and the optical fiber, and writing, the second long-period fiber grating having a predetermined period on the optical fiber, wherein the first and second long-period grating manufacturing units substantially simultaneously manufacturing the first and second long-period gratings, a light source, a measuring unit for measuring the output spectrum of the light generated in the light source and passed through the optical fiber on which the first and second long-period fiber gratings, and a controller for checking the output spectrum measured by the

measuring unit and adjusting the positions of the first and second amplitude masks to obtain a desired output spectrum.

Brief Description of the Drawings

The above objectives and advantages of the present invention will become more apparent by describing in detail a preferred embodiment thereof with reference to the attached drawings in which:

FIG. 1 is a schematic diagram of an apparatus for manufacturing long-period fiber gratings according to the present invention;

FIG. 2 illustrates an embodiment of an amplitude mask shown in FIG. 1;

FIG. 3 illustrates the process of determining the grating period by adjusting the position of an amplitude mask;

FIGS. 4A and 4B illustrate the grating periods depending on a change in x values when x+y=700 mm and 430 mm, respectively;

FIGS. 5A through 5D illustrate spectrums of a long-period grating filter having a predetermined extinction ratio at various wavelengths with respect to a change in x values, when x+y=430 mm;

FIG. 6 is a schematic diagram of an apparatus for manufacturing two-band long-period fiber gratings using the long-period fiber gratings according to the present invention; and

FIGS. 7A and 7B illustrate changes in wavelengths where coupling occurs over the keeping time, in which FIG. 7A illustrates a change in wavelengths where coupling occurs over UV exposure time and FIG. 7B illustrates a change in wavelength where coupling starts over the keeping time after H_2 loading; and

FIG. 8 illustrates the gain characteristics of an optical fiber amplifier depending on wavelengths.

Best mode for carrying out the Invention

The apparatus shown in FIG. 1 includes a UV laser source 100, a mirror 102 for changing the path of UV laser light generated from the UV laser source 100, a cylindrical lens 104 for focusing the laser light whose path is changed by the mirror

102, a dispersion unit 106 for dispersing laser light focused by the cylindrical lens 104, an amplitude mask 108 for selectively passing the light having passed through the dispersion unit 106, a slit 110 for allowing the laser light passed through the amplitude mask 108 to be irradiated only onto the portion where a long-period fiber gratings can be formed in an optical fiber 112, a light source 114, a measuring unit 116 for measuring the characteristics of the light passed through the optical fiber 112, and a controller 118 for determining the position of the amplitude mask 108 depending on coupling peaks and coupling peak wavelengths measured by the measuring unit 116.

The apparatus having the aforementioned configuration operates as follows. The mirror 102 reflects the laser light generated in the UV laser source 100 by a predetermined angle to change the traveling path of the laser light. The cylindrical lens 104 converges the reflected laser light onto an axis to be focused on the optical fiber 112. The dispersion unit 106 disperses the laser light passed through the cylindrical lens 104. A concave lens is typical used as the dispersion unit 106.

The amplitude mask 108 selectively transmits the light passed through the dispersion unit 106. The width of the slit 110 is determined depending on the band width of the spectrum of the long-period fiber grating. If the light passed through the slit 110 is irradiated into the optical fiber 112, the refractive index of a portion selectively exposed to the light in the core is changed. The measuring unit 116 measures the coupling peaks of wavelengths of the light generated from the light source 114 and passed through the optical fiber 112.

The controller 118 controls the period of the long-period fiber grating by adjusting the position of the amplitude mask 108 so that coupling occurs at a desired wavelength among wavelengths which pass through the long-period fiber grating formed by the above-described process.

FIG. 2 illustrates an embodiment of an amplitude mask shown in FIG. 1. The amplitude mask shown in FIG. 2 is formed on a thin metal substrate 200 having a thickness of about 0.2 mm, e.g., a stainless steel substrate, to have a transmission region 202 in which the light is transmitted with a period Λ_0 of several hundred micrometers and a non-transmission region 204. The transmission region 202 is

formed by CO_2 laser technology or chemical etching. Since the metal substrate 200 removes the limit of a damage threshold, high-power UV laser can be used as a source. The laser passes through the transmission region 202 so that the refractive index of an optical waveguide increases. The non-transmission region 204 which is made of a metal shields the UV laser.

FIG. 3 illustrates the process of determining the grating period by adjusting the position of an amplitude mask. Referring to FIG. 3, the laser light passed through a cylindrical lens 300 is dispersed by a concave lens 302 and masked by an amplitude mask 304 to then be selectively irradiated onto an optical fiber 306. Here, for the convenience of explanation, it is assumed that the distance between the focus of the concave lens 302 and the amplitude mask 304 is x and the distance between the amplitude mask 304 and the optical fiber 306 is y. Also, it is assumed that a half period of the amplitude mask 304 is a, angles of the laser light reaching the optical fiber 306 from the focus of the concave lens 302 via the amplitude mask 304 with respect to horizontal laser light 308 are γ, β and α, and the lengths of the laser light periodically irradiated onto the optical fiber 306 are C, B and A, respectively. Then, the following equations are satisfied.

$$\tan\alpha = \frac{3a}{x} = \frac{A}{x+y}$$

$$\tan\beta = \frac{2a}{x} = \frac{B}{x+y} \quad \ldots\ldots (2)$$

$$\tan\gamma = \frac{a}{x} = \frac{C}{x+y}$$

Assuming that Λ is the period of the grating written on the optical fiber 306, Λ is obtained using equation (2) to be expressed as:

$$\Lambda = \frac{2a(x+y)}{x} = \frac{\Lambda_0(x+y)}{x} \quad \ldots\ldots (3)$$

where Λ_0 is the period of the amplitude mask 304 and equals 2a.

In other words, when the distance between the concave lens 302 and the optical fiber 306 is adjusted, the period of a long-period fiber grating written on the optical fiber 306 is adjusted in accordance with the position of the amplitude mask 304.

FIG. 4A illustrates the grating period depending on a change in x values when x+y=700 mm. Table 1 shows the periods depending on x values. Here, the period of the amplitude mask 304 is 420 μm.

Table 1

x (mm)	Grating period (μm)
700	420.0
690	426.1
680	432.4
670	438.8
660	445.5
650	452.3
640	459.4
630	466.7
620	474.2
610	482.0
600	490.0
590	498.3
580	506.9
570	515.8
560	525.0
550	534.5
540	544.4
530	554.7
520	565.4

510	576.5
500	588.0
490	600.0
480	612.5
470	625.5
460	631.1
450	653.3

FIG. 4B illustrates the grating period depending on a change in x values when x+y=430 mm. Table 2 shows the periods depending on x values. Here, the period of the amplitude mask 304 is 420 μm.

Table 2

x (mm)	Grating period (μm)
430	420.0
420	430.0
410	440.5
400	451.5
390	463.1
380	475.3
370	488.1
360	501.7
350	516.0
340	531.2
330	547.3
320	564.4
310	582.6
300	602.0
290	622.8
280	645.0

270	668.9
260	694.6
250	722.4
240	752.5
230	785.2
220	820.9
210	860.0
200	903.0
190	950.5
180	1003.3

As the distance between the focus of a concave lens and the optical fiber, that is, x+y, increases, a variation in periods is lesser than to the variation in x values, which is advantageous for accurately adjusting the periods. In other words, in the case of designing a desired spectrum, the band width is adjusted by the width of a slit and x corresponding to the distance between the concave lens 302 and the amplitude mask 304 and y corresponding to the distance between the amplitude mask 304 and the optical fiber 306 are adjusted, thereby adjusting the coupling peak wavelength and coupling peak.

FIGS. 5A through 5D illustrate spectrums of a long-period grating filter having an extinction ratio of 5.4 dB at various wavelengths with respect to a change in x values, when x+y=430 mm, that is, coupling peaks in the case of placing the amplitude mask at location where x is 400 mm, 395 mm, 385 mm and 355 mm. As shown in the drawings, when $355mm \leq x \leq 400mm$, the coupling peak wavelengths ranging from 1300 nm to 1500 nm can be serially obtained.

Therefore, in order to manufacture a long-period fiber grating having a desired output spectrum, the band width is adjusted by the slit size, and the distance x between a concave lens and an amplitude mask and a distance y between the amplitude mask and an optical fiber are adjusted.

FIG. 6 is a schematic diagram of an apparatus for manufacturing two-band

long-period fiber gratings using the long-period fiber gratings according to the present invention. The two-band long-period fiber grating shown in FIG. 6 includes a UV laser source 600, a first long-period fiber grating manufacturing unit 610, a second long-period fiber grating manufacturing unit 620, a light source 630, an optical fiber 640, a measuring unit 650 and a controller (not shown).

The first long-period fiber grating manufacturing unit 610 includes a splitter 611, a first cylindrical lens 612, a first dispersing portion 613, a first amplitude mask 614 and a first slit 615.

The second long-period fiber grating manufacturing unit 620 includes a mirror 621, a second cylindrical lens 622, a second dispersing portion 623, a second amplitude mask 624 and a second slit 625.

Now, the process of manufacturing the two-band long-period fiber grating using the aforementioned configuration will be described. The first and second long-period fiber grating manufacturing units 610 and 620 form the long-period gratings having first and second periods on the optical fiber 640 substantially at the same time.

In detail, first, the splitter 610 splits the UV laser light generated in the UV laser source 600 in a ratio of 1:1 and partially reflects the same at a right angle (90°) to change the path of the light and allows the non-reflected light to travel straight; the first cylindrical lens 612 allows the incident UV laser light whose traveling path is changed by the splitter 610 to be focused through the axis where the beam size becomes large. Here, the focal point lands on the optical fiber 640. The first dispersing portion 613 disperses the light passed through the first cylindrical lens 612 to increase the beam size. The first amplitude mask 614 allows the light passed through the first dispersing portion 613 to selectively pass through the same. The width of the first slit 615 is determined by the bandwidth of a desired spectrum of the long-period fiber grating. If the light passed through the first slit 615 is irradiated into the optical fiber 640, the measuring unit 650 measures the coupling peaks at various wavelengths of the light generated in the light source 630 and passed through the optical fiber 640. The controller (not shown) adjusts the position of the first amplitude mask 614 so that coupling occurs at a desired wavelength of the long-

period fiber grating, thereby adjusting the period of the long-period fiber grating.

The UV laser light passed through the splitter 610 is reflected by the mirror 621 at a right angle (90°) so that its traveling path is changed. The second cylindrical lens 622 allows the incident UV laser light whose traveling path is changed by the mirror 621 to be focused through the axis where the beam size becomes large. Here, the focal point lands on the optical fiber 640. The second dispersing portion 623 disperses the light passed through the second cylindrical lens 622 to increase the beam size. The second amplitude mask 624 allows the light passed through the second dispersing portion 623 to selectively pass through the same. The width of the second slit 625 is determined by the bandwidth of a desired spectrum of the long-period fiber grating. If the light having passed through the second slit 625 is irradiated into the optical fiber 640, the measuring unit 650 measures the coupling peaks at various wavelengths of the light generated in the light source 630 and passed through the optical fiber 640. The controller (not shown) adjusts the position of the second amplitude mask 624 so that coupling occurs at a desired wavelength of the long-period fiber grating, thereby adjusting the period of the long-period fiber grating.

Here, the optical fiber 640 is sensitive to UV laser light and is obtained by loading hydrogen (H_2) into a germanium (Ge)-doped optical fiber. Hydrogen loading is done at a temperature of 80 to 90° C at a pressure of up to 100 atmospheres. The hydrogen-loaded fiber is maintained at room temperature. As time passes, hydrogen molecules diffused throughout the optical fiber slowly escape outside the cladding. Since hydrogen molecules escape, a difference in refractive indices between the core and the cladding is generated. Thus, depending on the keeping time of the optical fiber at room temperature, coupling conditions change.

FIG. 7A illustrates a change in wavelengths where coupling occurs over the UV exposure time, and FIG. 7B illustrates a change in wavelengths where coupling starts over the keeping time at room temperature after H_2 loading. As shown in FIGS. 7A and 7B, as the keeping time at room temperature gets longer, the coupled wavelengths are shifted toward longer wavelengths, and are then shifted toward shorter wavelengths in about 30 hours.

When the long-period fiber grating is manufactured by loading hydrogen into the optical fiber, since the spectrum measured by the measuring apparatus such as an optical spectrum analyzer is not stabilized, compensation must be made for obtaining an accurate spectrum for a final stabilized product. In particular, if an optical fiber amplifier has gain peaks at 1530 nm and 1550 nm, as shown in FIG. 8, the gains of both bands must be simultaneously flattened in order to obtain a gain-flattened optical fiber amplifier.

In the present invention, the gains can be simultaneously adjusted at both bands by adjusting the position of two amplitude masks 614 and 624. As the amplitude masks 614 and 624, the amplitude mask shown in FIG. 2 is suitably used. Also, position adjustment of the amplitude masks 614 and 624 and period adjustment of the long-period fiber grating are performed in the above-described manner.

Industrial Applicability

According to the present invention, the bandwidth of a long-period fiber grating can be adjusted by adjusting the size of a laser beam irradiated into an optical fiber. Also, amplitude masks can be easily manufactured at low cost and damage threshold power thereof is high. Also, since grating periods of the optical fiber are accurately adjusted, a filter having desired characteristics can be simply manufactured using a single mask.

Further, if two bands are simultaneously manufactured according to the present invention, since the possibility of wavelength shift due to hydrogen diffusion is removed, the filter design is simplified and the time necessary for manufacturing the filter is reduced. The light used for long-period fiber gratings has a power of output of about 120 mJ. In the present invention, since excimer laser light of high power (600 mJ) split in a ratio of 1:1 using a splitter is used, the long-period fiber grating according to the present invention can operate in a more stable manner with respect to the excimer laser light.

What is claimed is:

1. An apparatus for manufacturing a long-period fiber grating for periodically varying the refractive index of a core of an optical fiber by periodically irradiating UV laser light into the optical fiber, the apparatus comprising:

a light source for generating the UV laser light;

a mirror for reflecting the UV laser light generated in the light source at a predetermined angle and changing the traveling path thereof;

a lens for focusing the laser light whose traveling path is changed by the mirror;

a dispersing unit for dispersing the laser light passed through the lens; and

an amplitude mask positioned between the dispersing unit and the optical fiber, and having a transmission region in which the dispersed laser light is periodically transmitted to the optical fiber.

2. The apparatus according to claim 1, wherein the dispersing unit is a concave lens.

3. The apparatus according to claim 2, wherein the amplitude mask adjusts the period of the laser light irradiated into the optical fiber in accordance with its position.

4. The apparatus according to claim 3, wherein the period of the laser light irradiated into the optical fiber is determined by the following equation:

$$\Lambda = \frac{\Lambda_0 (x+y)}{x}$$

where Λ_0 is the period of the amplitude mask, x is the distance between the focus of the concave lens and the amplitude mask, and y is the distance between the amplitude mask and the optical fiber.

5. The apparatus according to claim 1, wherein the amplitude mask is made of metal.

6. The apparatus according to claim 1, further comprising a slit having a width determined by the bandwidth of the spectrum of the long-period fiber grating, the slit being provided between the amplitude mask and the optical fiber.

7. An apparatus for manufacturing a long-period fiber grating for periodically varying the refractive index of a core of an optical fiber by periodically irradiating UV laser light into the optical fiber, the apparatus comprising:

a light source for generating the UV laser light;

a mirror for reflecting the UV laser light generated in the light source at a predetermined angle and changing the traveling path thereof;

a lens for focusing the laser light whose traveling path is changed by the mirror;

a dispersing unit for dispersing the laser light passed through the lens; and

an amplitude mask positioned between the dispersing unit and the optical fiber, and having a transmission region in which the dispersed laser light is periodically transmitted to the optical fiber;

a measuring unit for measuring coupling peaks of a long-period fiber grating written on the optical fiber; and

a controller for adjusting the position of the amplitude mask for obtaining a desired coupling peak wavelength in accordance with the coupling peak wavelengths measured by the measuring unit.

8. An apparatus for manufacturing a two-band long-period fiber grating having different periods by aligning first and second amplitude masks having periodically repeated transmission regions and located at different positions from each other in the length direction of an optical fiber, in which UV laser light is irradiated into the two amplitude masks, the apparatus comprising:

a first long-period fiber grating manufacturing unit for determining the period of a first long-period fiber grating to be written on the optical fiber by adjusting the distance between the first amplitude mask and the optical fiber, and writing the first long-period fiber grating having a predetermined period on the optical fiber; and

a second long-period fiber grating manufacturing unit for determining the period of a second long-period fiber grating to be written on the optical fiber by adjusting the distance between the second amplitude mask and the optical fiber, and writing, the second long-period fiber grating having a predetermined period on the optical fiber, wherein the first and second long-period grating manufacturing units substantially simultaneously manufacturing the first and second long-period gratings.

9. The apparatus according to claim 8, wherein the first and second amplitude masks have transmission regions repeated at equal intervals.

10. The apparatus according to claim 8, wherein the first long-period fiber grating manufacturing unit comprises a splitter for splitting the UV laser light in a ratio of 1:1, reflects first light of the split laser light to change the traveling path thereof, and allowing second light to pass through the same toward the second long-period fiber grating manufacturing unit.

11. The apparatus according to claim 10, wherein the first long-period fiber grating manufacturing unit comprises:

a first lens for focusing the first light whose traveling path is changed;

a first dispersing unit for dispersing the laser light passed through the first lens; and

the first amplitude mask for allowing the first light dispersed by the first dispersing unit to be periodically transmitted in the length direction of the optical fiber.

12. The apparatus according to claim 11, wherein the dispersing unit is a concave lens.

13. The apparatus according to claim 12, wherein the period of the first long-period fiber grating is determined by the following equation:

$$\Lambda = \frac{\Lambda_0(x+y)}{x}$$

where Λ_0 is the period of the first amplitude mask, x is the distance between the focus of the concave lens and the first amplitude mask, and y is the distance between the first amplitude mask and the optical fiber.

14. The apparatus according to claim 10, further comprising a first slit having a width determined by the bandwidth of the spectrum of the first long-period fiber grating, the first slit provided between the first amplitude mask and the optical fiber.

15. The apparatus according to claim 10, wherein the second long-period fiber grating manufacturing unit comprises:

a mirror for reflecting the second light at a predetermined angle and changing the traveling path thereof;

a second lens for focusing the second light whose traveling path is changed;

a second dispersing unit for dispersing the laser light passed through the second lens; and

the second amplitude mask for allowing the second light dispersed by the second dispersing unit to be periodically transmitted in the length direction of the optical fiber at a different interval from the first long-period fiber grating manufacturing unit.

16. The apparatus according to claim 15, wherein the dispersing unit is a concave lens.

17. The apparatus according to claim 16, wherein the period of the second long-period fiber grating is determined by the following equation:

$$\Lambda = \frac{\Lambda_0(x+y)}{x}$$

where Λ_0 is the period of the second amplitude mask, x is the distance between the focus of the concave lens and the second amplitude mask, and y is the distance ~~between the second amplitude mask and the optical fiber.~~

18. The apparatus according to claim 15, further comprising a second slit having a width determined by the bandwidth of the spectrum of the second long-period fiber grating, the second slit provided between the second amplitude mask and the optical fiber.

19. An apparatus for manufacturing a two-band long-period fiber grating having different periods by aligning first and second amplitude masks having periodically repeated transmission regions and located at different positions from each other in the length direction of an optical fiber, in which UV laser light is irradiated into the two amplitude masks, the apparatus comprising:

a first long-period fiber grating manufacturing unit for determining the period of a first long-period fiber grating to be written on the optical fiber by adjusting the distance between the first amplitude mask and the optical fiber, and writing the first long-period fiber grating having a predetermined period on the optical fiber;

a second long-period fiber grating manufacturing unit for determining the period of a second long-period fiber grating to be written on the optical fiber by adjusting the distance between the second amplitude mask and the optical fiber, and writing, the second long-period fiber grating having a predetermined period on the optical fiber, wherein the first and second long-period grating manufacturing units substantially simultaneously manufacturing the first and second long-period gratings;

a light source;

a measuring unit for measuring the output spectrum of the light generated in the light source and passed through the optical fiber on which the first and second long-period fiber gratings; and

a controller for checking the output spectrum measured by the measuring unit and adjusting the positions of the first and second amplitude masks to obtain a desired output spectrum.

FIG. 1

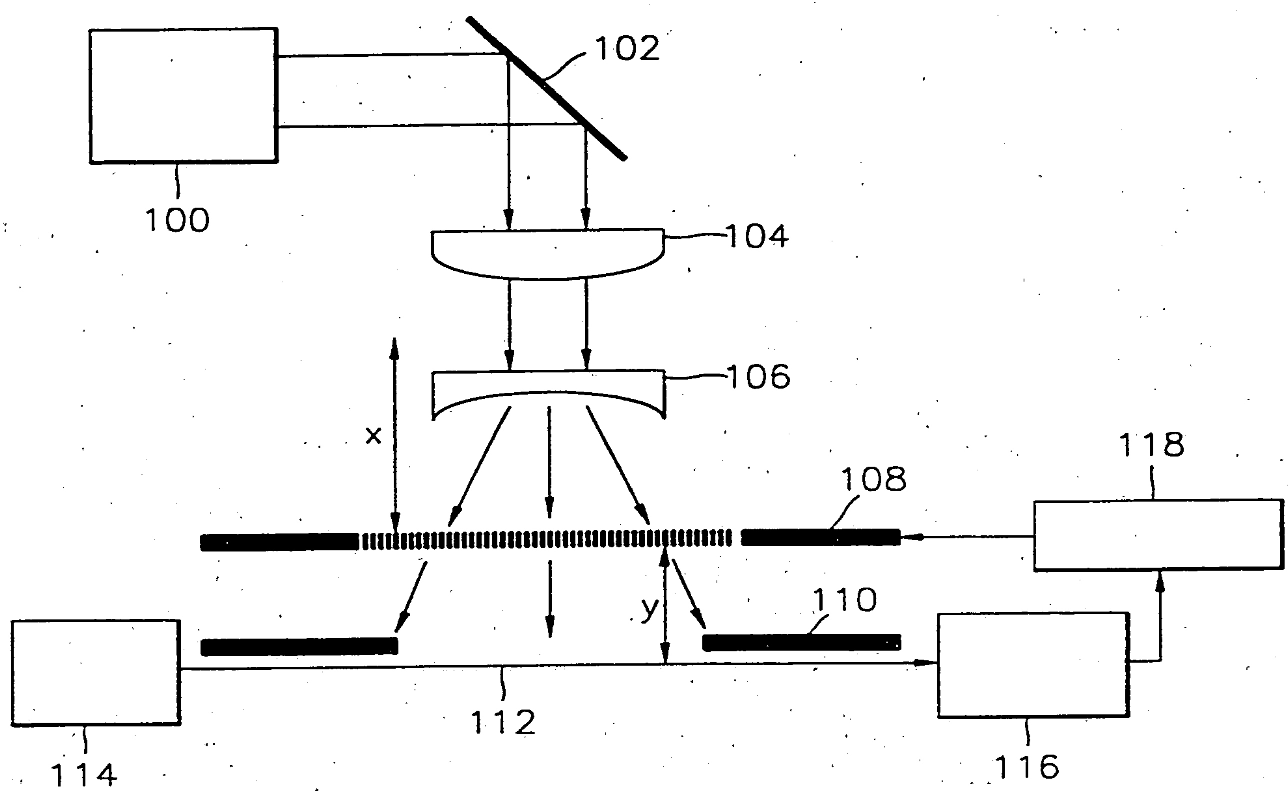
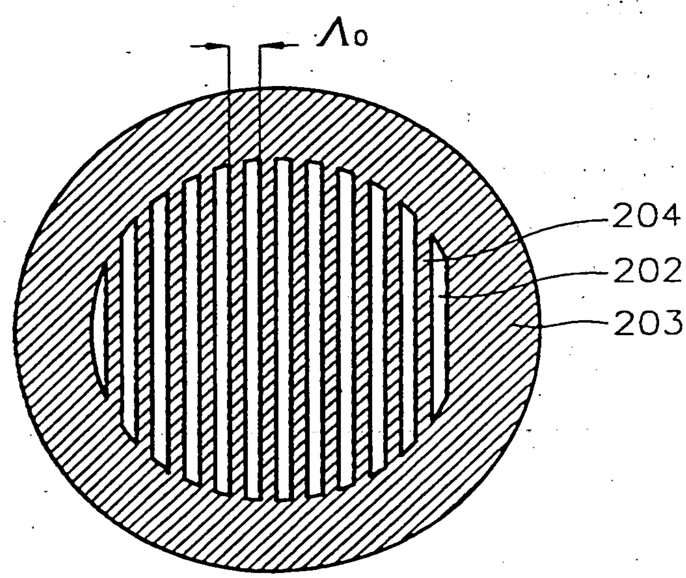


FIG. 2



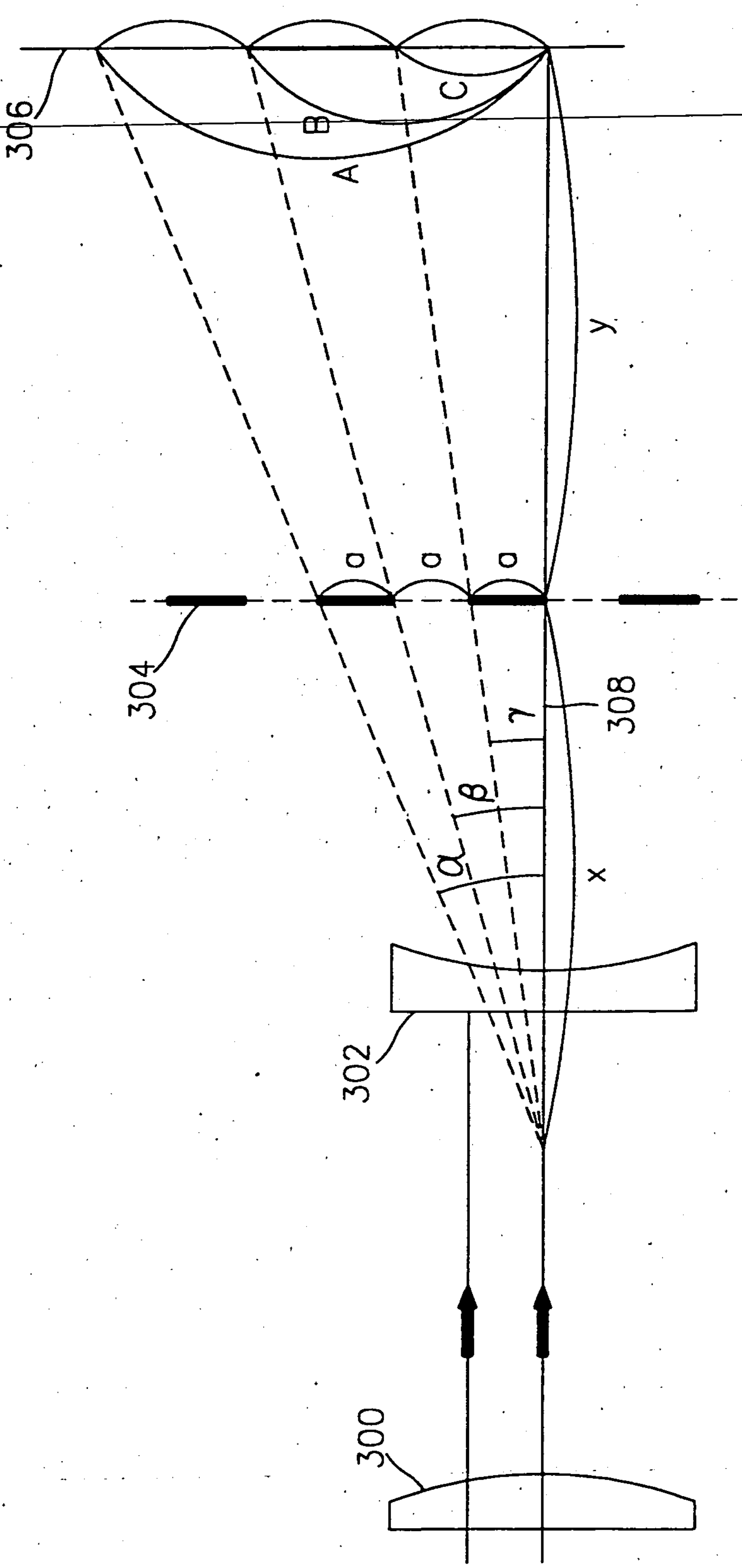


FIG. 3

FIG. 4A

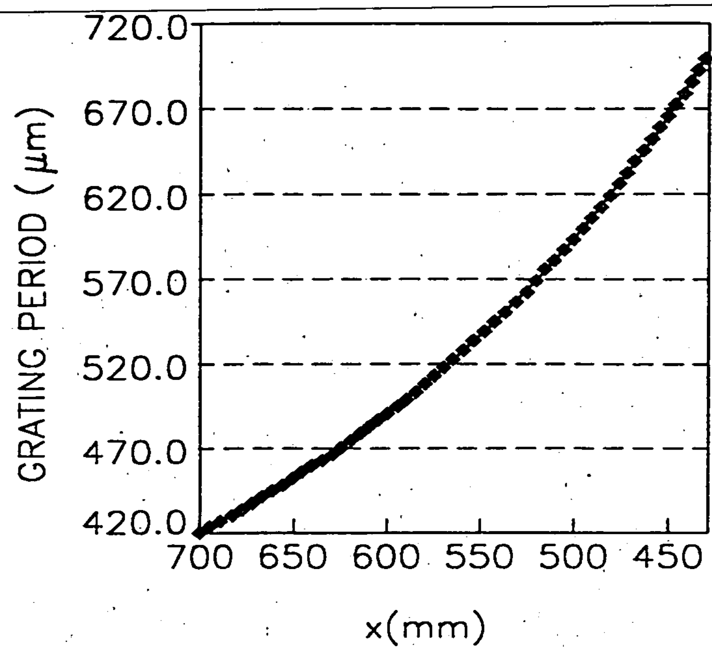

720.0
670.0
620.0
570.0
520.0
470.0
420.0
GRATING PERIOD (μm)
700
650
600
550
500
450
x(mm)

FIG. 4B

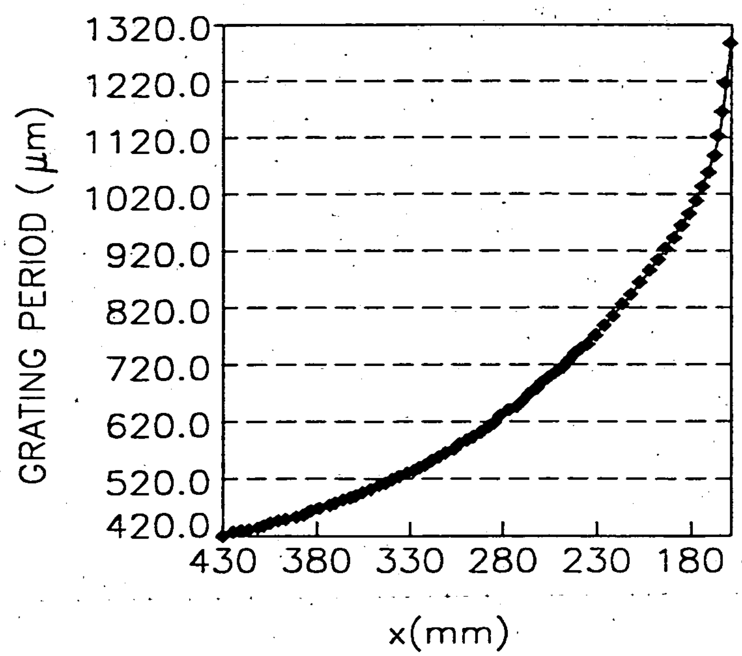
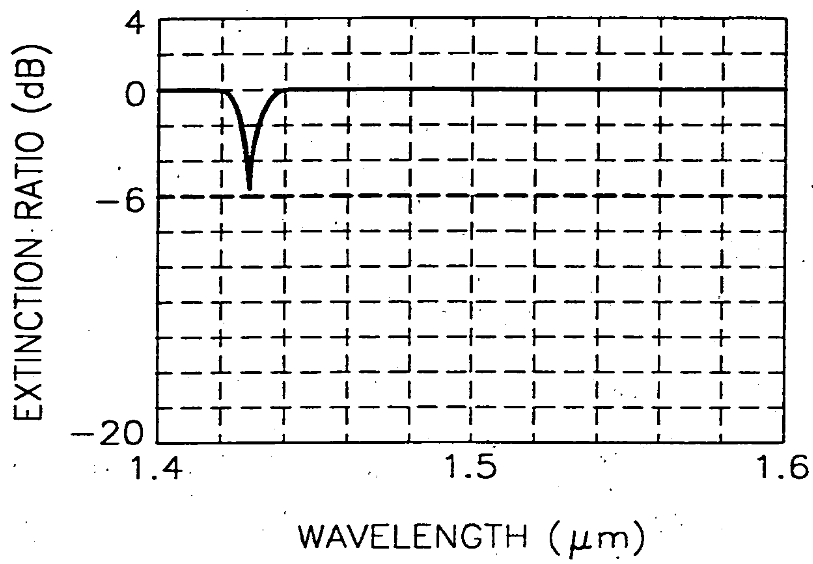
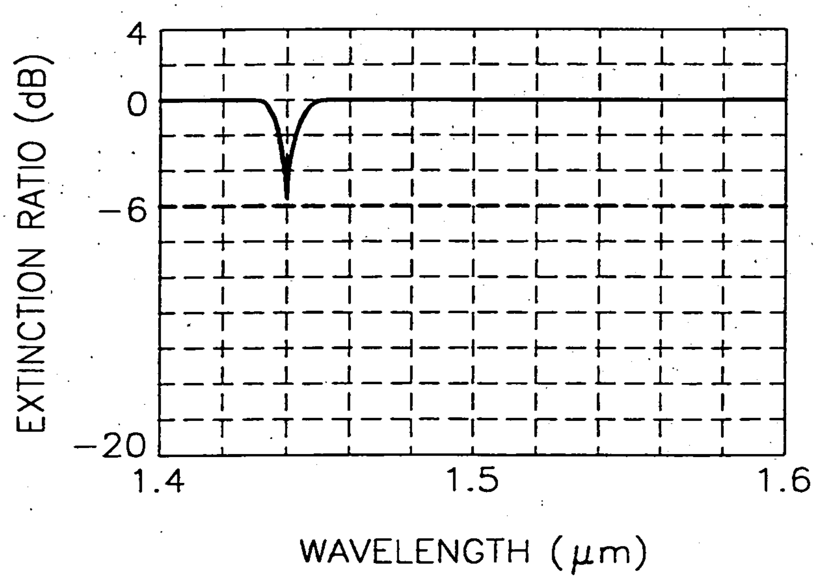

1320.0
1220.0
1120.0
1020.0
920.0
820.0
720.0
620.0
520.0
420.0
GRATING PERIOD (μm)
430
380
330
280
230
180
x(mm)

FIG. 5A



4
0
-6
-20
1.4
1.5
1.6
EXTINCTION RATIO (dB)
WAVELENGTH (μm)

FIG. 5B



4
0
-6
-20
1.4
1.5
1.6
EXTINCTION RATIO (dB)
WAVELENGTH (μm)

FIG. 5C

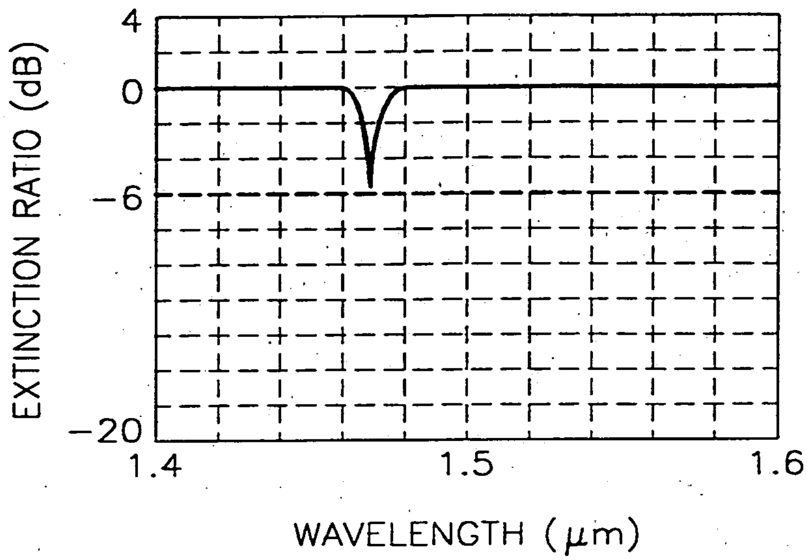
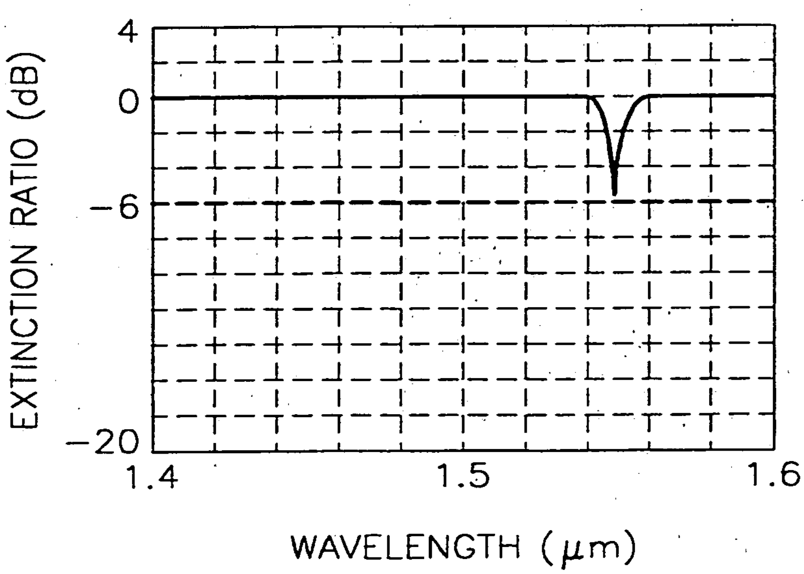

4
0
-6
-20
1.4
1.5
1.6
EXTINCTION RATIO (dB)
WAVELENGTH (μm)

FIG. 5D


4
0
-6
-20
1.4
1.5
1.6
EXTINCTION RATIO (dB)
WAVELENGTH (μm)

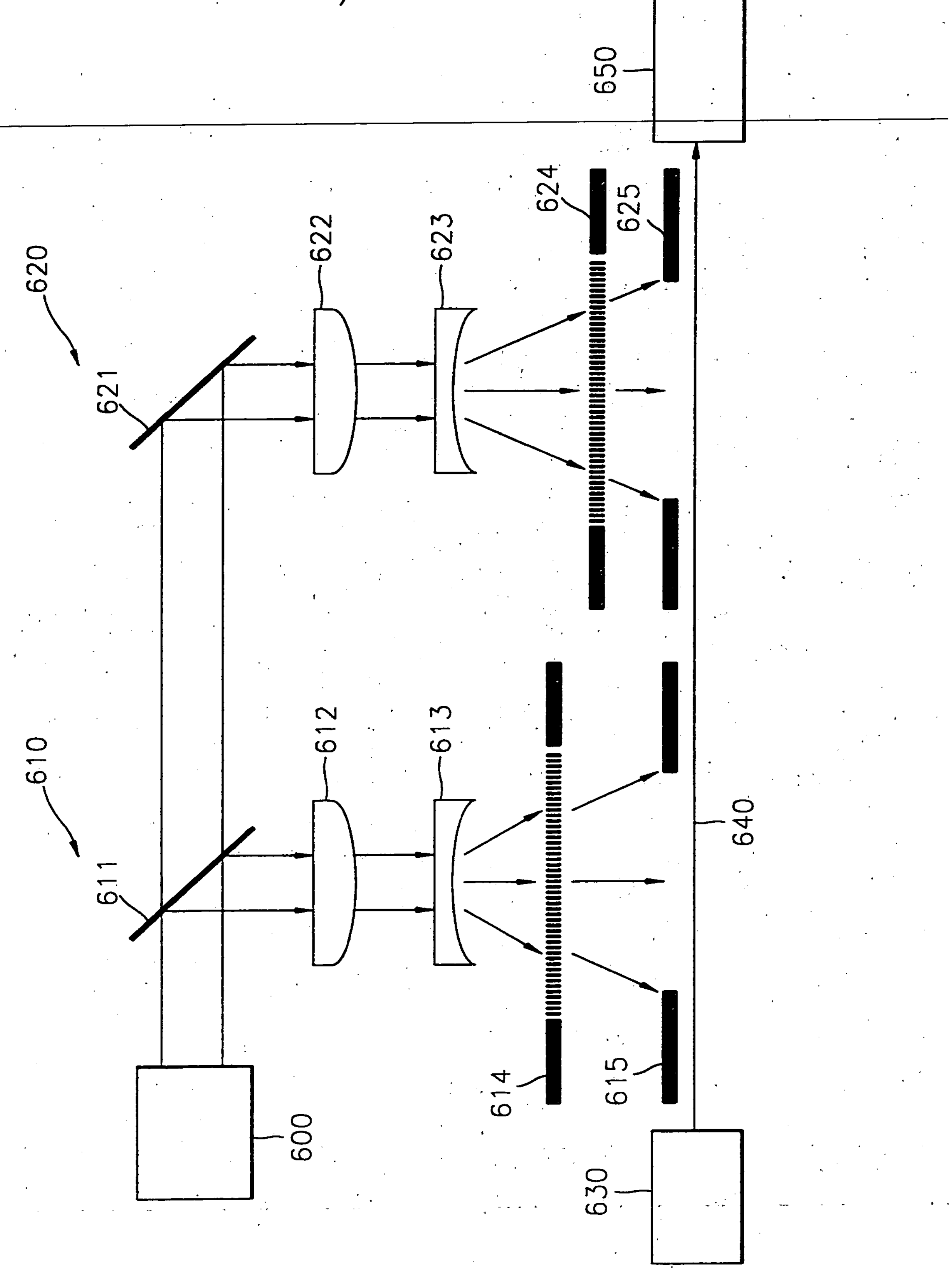


FIG. 6

FIG. 7A

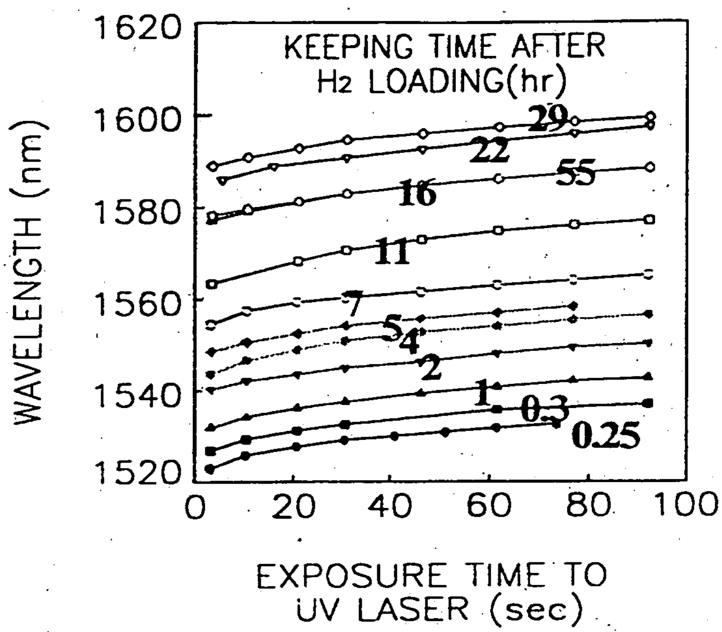

KEEPING TIME AFTER
H_2 LOADING(hr)
1620
1600
1580
1560
1540
1520
WAVELENGTH (nm)
0
20
40
60
80
100
29
22
55
16
11
7
5
4
2
1
0.3
0.25
EXPOSURE TIME TO
UV LASER (sec)

FIG. 7B

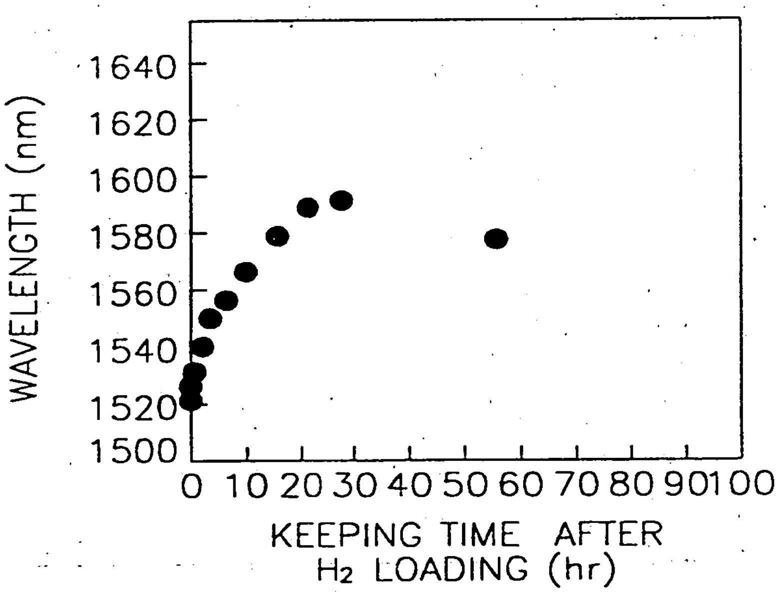
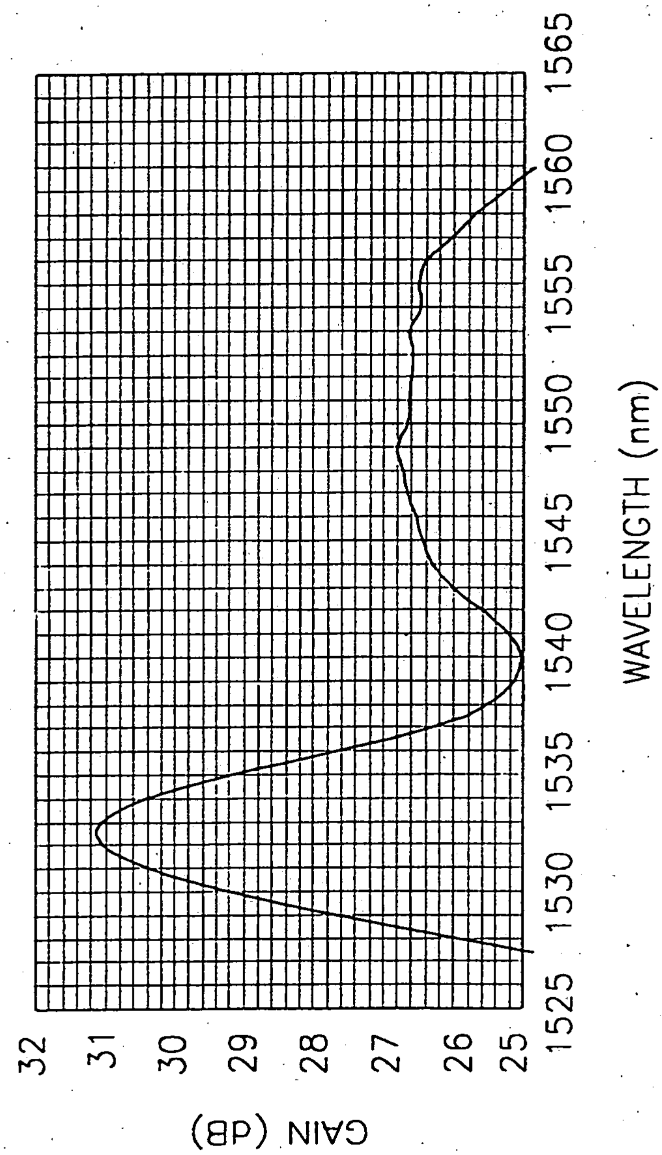

1640
1620
1600
1580
1560
1540
1520
1500
WAVELENGTH (nm)
0 10 20 30 40 50 60 70 80 90100
KEEPING TIME AFTER
H_2 LOADING (hr)

FIG. 8


GAIN (dB)
32
31
30
29
28
27
26
25
1525
1530
1535
1540
1545
1550
1555
1560
1565
WAVELENGTH (nm)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR 99/00443

A. CLASSIFICATION OF SUBJECT MATTER

IPC^7: G 02 B 6/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC^7: G 02 B 6/16, 5/18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPOQUE (EPODOC, WPI); QUESTEL (INSPEC)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2289771 A (NORTHERN TELECOM) 29 November 1995 (29.11.95) page 5, line 31 - page 7, line 24.	1,3,7,8,19
A	EP 0805365 A2 (FUJIKURA LTD.) 05 November 1997 (05.11.97) fig. 7, 8; page 7, line 15 - page 9, line 54.	1,2,5,7,8,11,12, 15,16,19
A	WO 95/22068 A1 (THE UNIVERSITY OF SIDNEY) 17 August 1995 (17.08.95) fig. 5-7B; page 8, line 24 - page 10, line 13.	1,7,8,19
A	US 5604829 A (BRUESSELBACH) 18 February 1997 (18.02.97) col. 3, line 28 - column 5, line 34.	1,7,8,19
A	US 4725110 A (GLENN et al.) 16 February 1988 (16.02.88) abstract; fig. 4.	8,19

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
„A" document defining the general state of the art which is not considered to be of particular relevance
„E" earlier application or patent but published on or after the international filing date
„L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
„O" document referring to an oral disclosure, use, exhibition or other means
„P" document published prior to the international filing date but later than the priority date claimed
„T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
„X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
„Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
„&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02 November 1999 (02.11.99)	13 December 1999 (13.12.99)

Name and mailing adress of the ISA/AT	Authorized officer
Austrian Patent Office Kohlmarkt 8-10; A-1014 Vienna Facsimile No. 1/53424/200	Gronau Telephone No. 1/53424/348

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR 99/00443

Im Recherchenbericht angeführtes Patentdokument Patent document cited in search report Document de brevet cité dans le rapport de recherche	Datum der Veröffentlichung Publication date Date de publication	Mitglied(er) der Patentfamilie Patent family member(s) Membre(s) de la famille de brevets	Datum der Veröffentlichung Publication date Date de publication
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